Sonoma Technology

Technical Memorandum

May 11, 2023 STI-922025-7851-TM

To: Mark Brown and Charlotte Jourdain, Marin Wildfire Prevention Authority (MWPA)

From: Samantha Kramer, PhD, Tami Lavezzo, Hilary Hafner, Charles Scarborough, and Bryan Penfold

Re: Findings from the Task 3 Data Review for the Marin Evacuation Ingress/Egress Risk Assessment Project and Summary of Baseline Modeling Scenarios for Five Test Areas in Marin County

Introduction

In 2022, the Marin Wildfire Prevention Authority (MWPA)[1] funded a project to assess evacuation route vulnerability and develop a planning tool. The planning tool is intended to be used by MWPA member agencies, county officials, public works departments, and transportation planners to help identify and prioritize actions and/or projects that can mitigate risks associated with evacuation throughout the county. The scope of the Marin Evacuation Ingress/Egress Risk Planning Tool project includes constructing an inventory of risk factors and using dynamic models of wildland fire spread, communications processes, and traffic flow to simulate wildfire evacuation scenarios. The modeling and risk analysis will be used to develop a risk index for each roadway in the county to help identify the most vulnerable evacuation routes and prioritize mitigation projects that may improve those routes.

Using the risk factor inventory, scientific modeling scheme, and the results of the risk analyses, a geographic information system (GIS)-based evacuation risk planning tool will be developed. MWPA member agencies and other partners will use this tool to inform their mitigation work plans, evaluate the impact of proposed or completed improvements, prioritize distribution of funds, and seek new

[1] The Marin Wildfire Protection Authority (MWPA) is a newly formed 17-member Joint Powers Authority (JPA), created with the support of Marin County residents who passed Measure C in March 2020 with 70.8% voter approval. The MWPA was formed to develop and implement comprehensive wildfire prevention, mitigation, and emergency preparedness activities throughout almost all of Marin County, in coordination with its 17 local member agencies. One key element of MWPA's mission includes the improvement of evacuation routes for safe and orderly evacuation, which grounds the need for the evacuation route risk assessment project.

funding for projects. Fire and law enforcement agencies are expected to use the tool to obtain a detailed picture of risk at various levels of aggregation, which will inform evacuation preparedness activities and decisions. This planning tool and the underlying data will help assess the need for mitigation projects. The results from this work are not intended to help manage or train for evacuations. It is solely a planning tool.

Before beginning the evacuation risk assessment work, a literature review was performed to evaluate the state-of-the-science in evacuation dynamics, and specifically to:

- Define evacuation goals and evacuation success
- Identify the leading causes of injuries and fatalities for past wildfire evacuations, and key risk factors based on these past incidents
- Identify current best practices and recommendations related to evacuation planning
- Identify and understand models and tools developed by other organizations and evaluate their application for use in Marin County

The results of the literature review are documented in a report entitled *Literature Review of the State-of-the Science in Wildfire Evacuation* dated October 7, 2022.[2] This technical memorandum documents 1) the tools and datasets used in computer modeling simulations and accompanying data sources and 2) the datasets identified and used by Sonoma Technology's team to perform the evacuation ingress/egress risk assessment.

In parallel with the literature review, a data review was conducted. The objectives of the data review were to:

- Identify the datasets and key risk factors used to model evacuation dynamics based on the literature review
- Identify and acquire datasets for Marin County to be used for the evacuation risk assessment
- Identify critical data gaps

A complete data dictionary is included in Appendix A of this memorandum, which provides detailed descriptions of the datasets used for the Marin County evacuation risk assessment.

[2] https://www.marinwildfire.org/news/the-state-of-the-science-in-wildfire-evacuation-modeling-a-literature-review

Summary of Findings from the Data Review

The results from the literature review provided a long list of data types and sources that have been used to assess fire risk, risk perception, and evacuation dynamics. However, not all datasets are appropriate or applicable to Marin County. Conversely, Marin County has a rich dataset of information - some of which is not available for other regions. As part of the data review, the variables identified in the literature were assessed for availability and applicability to Marin County. Each dataset was also assessed for validity, completeness, and quality. To accelerate the work schedule and deliverables, the review was focused on existing data sources needed for the current conditions risk assessment. No critical data gaps were identified for modeling evacuation dynamics for Marin; however, in some cases, higher-resolution data and surveys may help augment the results for future updates to the evacuation risk assessment.

> **Key Finding**
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> Marin County has a rich dataset of information, and no critical data gaps were identified for modeling evacuation dynamics.

Leading Causes of Civilian Fatalities during Wildfire Evacuation

It is important to understand the determinants of evacuation risk factors and evacuation success to ensure the appropriate data are available to perform evacuation risk assessment modeling. Key findings from the literature showed three major factors contribute most to civilian fatalities:

1. Extreme fire behavior conditions
2. Failures and/or delays in alerting and communications systems
3. Delays in evacuee departure due to last-minute evacuations or an inability to evacuate

Extreme fire behavior conditions. The primary risk factor and threat to a successful evacuation is extreme and uncontrollable fire behavior in or near populated areas and along evacuation routes. In situations with extreme, wind-driven fires, (1) flames can spread very quickly, (2) spot fires can merge and create a multi-fire complex, and (3) fires can expand into the wildland urban interface (WUI) or suburban neighborhoods before people are able to evacuate.

Failures and/or delays in alerting and communications systems. Communication failures of various types resulted in time being lost to evacuate safely from numerous fires. Compounding the problems observed with past fires, Marin County is also at risk from PG&E Public Safety Power Shutoffs (PSPS) during extreme fire weather conditions. This could leave residents without power and impede their ability to receive communications through traditional avenues, such as television and radio. Communication failures have also resulted from fire impacts (1) directly, such as with lost cell towers, and (2) indirectly, such as when successful contact to portions of the population is impossible. Marin has population subgroups at greater risk for communication obstacles, including:

1. Elderly individuals who may have limited access to technology
2. Unhoused individuals
3. People who are less trusting of government-issued information
4. Individuals who are dependent on public transportation systems
5. Tourists and visitors who may not be familiar with wildfire risks, road networks, or evacuation alert systems

Delays in evacuee departure due to last-minute evacuations or an inability to evacuate. Finally, a main contributor to civilian fatalities is delayed evacuation–a lesson learned in both the U.S. and Australia. A key insight from past studies is *the importance of age*. Most civilian fatalities during the Camp Fire, for example, were individuals aged 65 and older who became trapped in their homes or on their properties for reasons including: failure to receive alerts and evacuation orders, inability to mobilize due to lack of transportation or health condition, inability to perceive an immediate threat, or their decision to remain at home.

To assess these key risk factors using modeling, the underlying datasets must be available and of adequate quality.

Evacuation Goals and Success

The principal objective of a wildfire evacuation is to protect the public from the threat of wildfire without injury or death. Based on the review of the current literature, in an ideal scenario, the goals for a manageable and successful evacuation include:

1. Immediate identification of wildfire threat and ongoing understanding of the fire's behavior
2. Timely and successful dissemination of evacuation alerts and communications
3. Timely and organized departure of residents and the public
4. Safe and efficient evacuation
5. Arrival at designated or pre-determined safe spaces unharmed

As shown in **Figure 1**, the five goals identified as key determinants for evacuation success have been color-coded. The same color scheme is used in other figures throughout this document to provide related information about each goal.

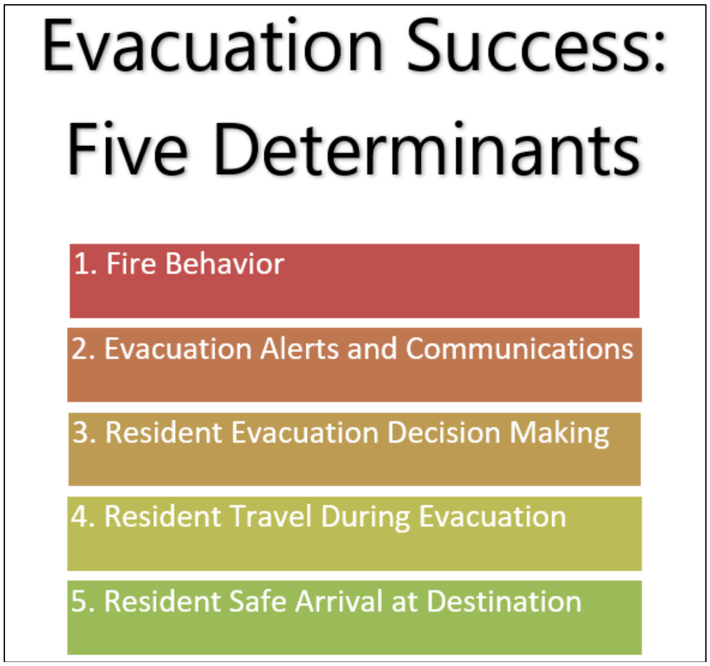

Figure 1. Five determinants of evacuation success identified in the literature.

At each stage of a wildfire evacuation, there are several risk factors that can affect the overall outcome (Figure 2). It is important to understand these risk factors when constructing the approach for evacuation modeling to ensure adequate data are available to support modeling efforts. Wildfire conditions, such as rapid fire spread and extreme fire behavior, can exceed suppression resources quickly and reduce the amount of time to provide evacuation warnings and orders. Impacts to key infrastructure, such as cell towers, can delay evacuation notices, especially in wilderness areas and for residents with limited access to technology. Time of day, notification time, education, demographics, and family dynamics all impact a person's decision and capability to stay home or leave during an evacuation.

The number of people leaving at any given time, by various methods, impacts road demand. Road demand affects road network saturation and congestion. Road congestion points, or "choke points," can greatly impact efficient egress for evacuees and ingress for emergency vehicles at the local and county level. The number and location of established safe destination points also greatly impacts the road saturation over time and are key for reducing the burden of vehicles on a saturated roadway. Mitigation methods can reduce the risk at each stage from wildfire ignition to safe shelter. These can include improved roadways and signage, smart traffic lights, resident education, hardening of key infrastructure and designated safe spaces, vegetation management along evacuation routes, and resource planning and allocations.

Based on the review of the current literature, for each of the five risk categories (Figure 1), there are many variables and corresponding datasets that provide valuable information for wildfire evacuation planning. A comprehensive list of these variables and datasets is contained in Appendix B and color-coded based on the five risk categories shown in Figure 1. In practice, all variables listed in Appendix B cannot be directly implemented into a single modeling framework; however, when conducting modeling, the best practice is to use the most current, representative, and highest resolution (both time and space) data available.

Wildfire Evacuation Risk Factors

Extreme Fire Behavior	• Vegetation Species are Highly Flammable • Vegetation and Soil are Dry • Weather Conditions are Extreme (Wind, Temp, RH) • Home Hardening Insufficient • Fire Line Intensity • Burn Probability • Resources are Limited

Communications Insufficient or Delayed	• At-Risk Area is Uncertain
	• Information is Unclear
	• Language Barrier
	• Communication Tools are Down
	• Evacuation Order Does Not Reach All Populations
	    • Homeless
	    • Elderly
	    • Visitors/Tourist

Residents Depart Too Late	• Residents Do Not Start from Home
	• Seek Information Before Depart
	• Access to Transportation or Medical Assistance
	• Pets or Livestock
	• Demographics or Family Dynamics
	    • Age
	    • Ethnicity
	    • Number of Persons

Evacuees Exposed to Fire or Danger Enroute	• Routes Become Blocked • Lack of Information to Re-Route • Multiple or Erratic Stops on Route • Traffic Congestion or Collisions Prevents Egress • Destination Unknown • Not Enough Time to Avoid Danger

Congestion and Continued Risk	• Evacuees Return Home Too Soon
	• Evacuees Do Not Have Current Information
	• Road Congestion Persists on Evacuation Route
	    • Vehicles Still in Network
	    • Unknown or Multiple Destinations

Figure 2. Summary of wildfire evacuation risk factors.

Datasets Used for Evacuation Modeling Based on Current Literature

There are numerous evacuation risk factor variables that are useful for modeling, as well as background map layers to add geographic description and context (Figure 3). Road quality parameters such as road type, number of lanes, signage, centerline markings, effective road width, and street parking density can inform road management mitigation projects but are also inputs for modeling location-specific traffic scenarios. Some examples of this include signage for right-of-way or street parking restrictions during Red Flag Warning[3] days, and improvements to street markings. Roadways with large trees or dense vegetation can also be at risk for road blockages during an evacuation. In addition, narrow winding roads and complex intersections may be more affected during poor-visibility conditions. Intersection control mechanisms such as stop or yield signs, traffic lights, and personnel available to assist with traffic control can inform additional mitigation actions to improve wildfire evacuation. These could include installation of smart traffic lights at large intersections along evacuation routes, deploying signs at non-signaled intersections, and increasing traffic control staff on Red Flag Warning days. Wildfire risk is characterized by fire environment variables and the fire behavior/growth model; emergency alert and decision making by the communication and decision model; and evacuation and safe space by the traffic model.

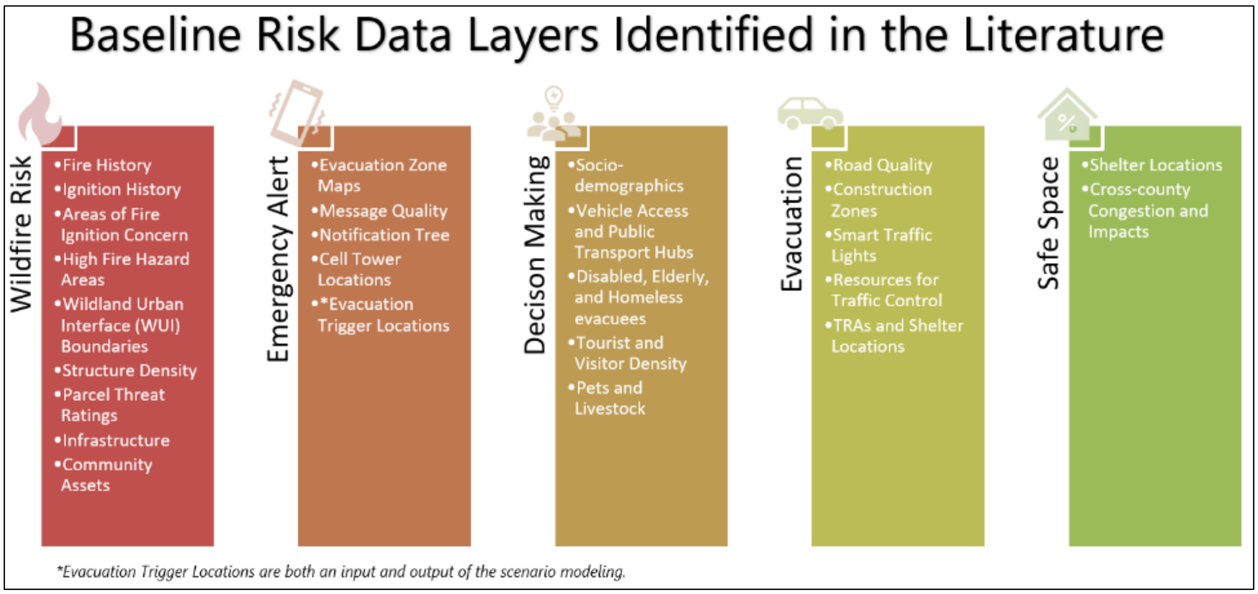

Figure 3. Baseline risk data layers identified in the literature.

Fire Datasets

To characterize wildfire threat, several datasets were identified in the literature including (but not limited to) fire spread, burn probability, zoning, structure characteristics, and fire management potential. Fire management potential components such as topography, access/ingress roads, fuel loads along ingress/egress roads, distance from fire station(s), and water availability, can inform areas where fire containment may be possible to achieve. These wildfire risk layers can inform mitigation projects including modifying or reducing fuel loads along ingress/egress roads, extending water

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[3] National Weather Service (https://www.weather.gov/media/lmk/pdf/what_is_a_red_flag_warning.pdf).

lines, early fire detection devices, and road improvements to improve ingress and egress, all of which may increase emergency response time and likelihood of suppression.

Communication Datasets

For the emergency communication network, maps indicating the method(s) by which people communicate (e.g., smartphone, computer, landline phone) can inform areas that may need redundancy in notification protocols. For example, in areas with limited internet and phone access and/or areas with power outages, in-person evacuation notices may be needed. Maps showing the locations of cell phone towers and communications infrastructure can inform areas that may need additional hardening and vegetation management to help protect the reliability of the communication network.

Infrastructure Datasets

Key infrastructure can also include gas stations and power stations, which must remain operational during an evacuation. Maps showing demographics, vehicle density, transportation hubs, large population centers, homeless serving institutions, and livestock areas can inform tailored education and messaging before and during an evacuation. These map layers also indicate the number of people in each area at the time of an evacuation and can help identify communities or population groups that may take more time to notify and mobilize. In addition, these map layers can inform areas where increased capacity for public or emergency transportation may be needed as well as areas or facilities that should be considered for emergency temporary safe shelters. These are actionable mitigation strategies to help increase the likelihood of evacuating, encourage orderly response, and provide people with access to vehicles and/or transportation options.

Evacuation Scenario Modeling

For this study, fire modeling; communication and decision modeling; and traffic modeling were used to identify problematic situations and areas that can be improved with mitigation projects as shown in **Figure 4**. The modeling methodology was implemented and demonstrated for five test areas throughout Marin County including Fairfax, Novato, San Rafael, Tamalpais Valley, and Inverness. Once tested and demonstrated, the modeling methodology was expanded to the county and the modeling results were combined with background data layers describing the fire environment, roadways, and geographic features across the county.

The PyreCast fire model ingests fuel model and fuel moisture data, topography, meteorological data, and ignition locations to simulate fire spread, intensity, and time of arrival. Running multiple scenarios with adjustments for ignition locations and weather help predict rapid fire spread and the conditions that may overwhelm existing resources. The fire spread and time of arrival model outputs are then used as input to the communication and decision model (C&D model).

The C&D model input includes the fire model output and arrival time information; micro-analysis zones (MAZs)[4] and demographic data from the Transportation Authority of Marin Demand Model (TAMDM) dataset; alert methods including local 911 data and the number of people subscribed to AlertMarin; time of day; transportation access; resident decision to stay or depart; and resident location and time of departure. All of this information determines the geographic distribution of evacuees, road demand, method of evacuation, and the number of residents remaining in the evacuation zone due to missed communication or deciding to stay. This information is then used as input to the traffic model to simulate different road-demand scenarios.

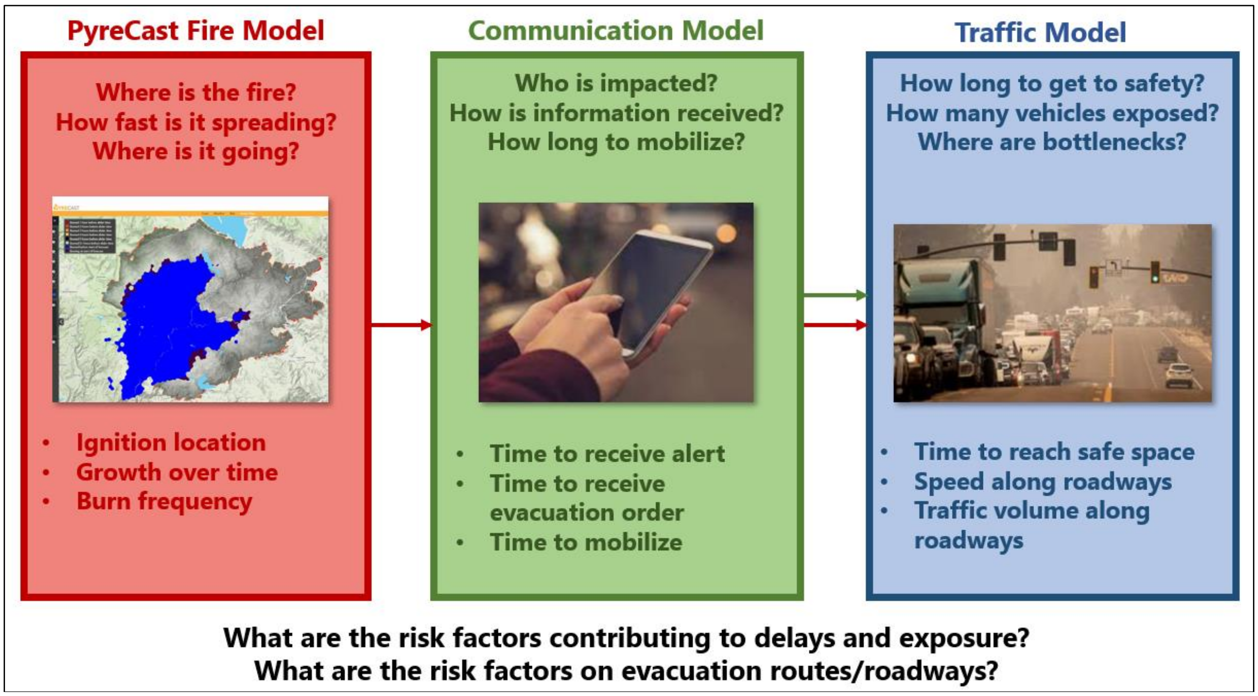


Figure 4. Overview of the scenario modeling for each of the five test areas.

The traffic model input includes the origin and time of departure from the C&D model and can incorporate information on time of day and ambient congestion, road quality, evacuation routes and re-routing, and evacuation destinations. Scenarios can be designed for visibility challenges, road blockages, road improvements or changes, or traffic policy changes. Simulations can be aggregated to determine situations in which roadways or intersections have high congestion that can be mitigated with new traffic management policies or infrastructure updates. They can also determine the average time to evacuate safely under different conditions. Simulations can identify areas in

[4] In travel demand modeling, a planning region is divided into geographic areas called Traffic Analysis Zones (TAZs). Each TAZ polygon contains employment, population, school enrollment and other data. The origins and destinations of trips are mapped to TAZs. Micro Analysis Zones (MAZs) add higher spatial resolution to travel demand modeling. Socioeconomic data is collected and projected at the neighborhood, or block-level census data, the smallest level of spatial aggregation.

which emergency response ingress is blocked or delayed due to evacuation congestion or how policies can improve ingress.

In whole, we produced a range of scenarios for best-case (e.g., meeting all evacuation goals in an efficient and orderly manner) through worst-case scenarios (e.g., communication failures, road blockages, lack of transportation availability, rapid fire spread) to compare fire arrival time, number of persons in unsecure locations, persons in a secure location, and evacuation conditions over time.

The literature review provided examples and case studies that implemented fire, communication, and traffic models in sequence. However, the previous modeling studies and tools were implemented for different purposes and outcomes then defined for the Marin Ingress/Egress Evacuation Risk Assessment. Though the Marin Evacuation Ingress/Egress Risk Assessment goal is to develop actionable mitigation projects to improve wildfire evacuation, previous modeling studies helped to inform the modeling approach for this project. The modeling work performed as part of this project will help inform and prioritize future mitigation projects such as road widening, vegetation management along roadways, parking policy changes, intersection control devices, and road signage improvements.

Datasets Used to Perform the Marin Evacuation Ingress/Egress Risk Assessment

In summary, the data review task did not identify any key missing datasets that would prevent the modeling work. The datasets used to initialize and run each model are listed in **Table 1**, as well as background data layers used in aggregate evacuation difficulty scores. Detailed information on each dataset can be found in the accompanying Data Dictionary (Appendix A), cross referenced by Dataset Name. Similarly, the output from each model and relevant base layers used to perform the risk assessment are listed in **Table 2**. These datasets can also be found in the Data Dictionary with additional detail on quality control and post processing procedures.

Though the datasets listed provide adequate information for the dynamic modeling to be performed, there are several ways to improve the certainty and robustness of the findings. Future data enhancements should include in-parcel home hardening and vegetation data, which is being collected through the MWPA home inspection program. Additional demographic data including household pets, length of residence, and need for medical assistance, would also be valuable information to better characterize communication challenges and likelihood to evacuate. Additional geographic detail and confidence in the number and location of National Oceanic and Atmospheric Administration (NOAA) radios, tourist populations, and unsheltered populations would also provide value for understanding communication challenges. For infrastructure, road width is the most critical variable which is not systematically available. Though some assumptions can be made based on road types, systematic and measured road widths will provide significant improvements to the evacuation assessments. County-wide identification of shelter locations would improve planning and traffic assessments. Lastly, we recommend updates to all variables including the fuels and fire behavior data to represent recently completed and upcoming fuel reduction projects, signal installments, and other changes.

Table 1. The variables used to initialize each model (input), the names of the datasets used for model input (see matching name in Data Dictionary for more information), and the use of the data in the modeling framework.

Inputs	Dataset Use
Vegetation, Fuel and Landscape	Factors for topography, fire behavior, spread, and burn rates
Weather	Factors for fire behavior, spread, and burn rates; includes wind speed, wind direction, relative humidity
Fuel Moisture	Factor for fire behavior, spread, and burn rates
Areas of Ignition Concern	Areas of concern for potential fire ignitions
Ignition Locations	Point of ignition for fire modeling
Inputs	**Dataset Use**
Population	Factor for number of evacuees, time to depart by micro-analysis zone (MAZ)
Population Clusters	Locations of business districts, schools, convalescent homes; retirement communities, and social clubs with their geographic locations and distance to main roads where large clusters of people would need to evacuate from and may require assistance
Demographics	Factor for method of communication, wildfire risk perception, time of awareness, and time to depart
Evacuation Routes	Roadways used for evacuation
Shelter Locations (Arrival Points)	Short- and/or long-term destination points for evacuees
Cell Tower Locations	Factor for method of communication and time of awareness
Communication Dead Zones	Factor for method of communication and time of awareness
Types of Communication by Population	Factor for method of communication and time of notification/awareness (risk cognition)
Number of Alert Marin Subscribers	Factor for method of communication and time of awareness

Inputs	Dataset Use
Number of People with NOAA Radio/SNS/TV	Factor for method of communication and time of risk cognition
Number of People with Internet access	Factor for method of communication and time of risk cognition
Estimated number of evacuating vehicles	Number of evacuees affecting the rate of traffic flow
Fire Location	Fire arrival time at MAZ zones for risk perception and cognition
Inputs	**Dataset Use**
Road Network	Evacuation route, number of vehicles on roadway, road congestion, re-routing, distance to evacuate, intersections, road nodes and connections
Road Characteristics	Includes factors such as narrow roads, roads with street parking, steep slopes affecting effective road width, road obstruction, speed of travel, road congestion
Traffic Control	Factor for road congestion, evacuation route, and re-routing, includes traffic lights, stop signs, and in-person direction
Travel Demand	Factor for road congestion, location of vehicles entering roadway; includes time-dependent origin and destination of each vehicle; dependent on the time of risk cognition, when individuals perceive the risk and decide to act
Modes of Transportation	Factor for road congestion, method of travel, number of people per vehicle, location of vehicles entering roadway
Fire Arrival at Nodes	Number of people on roadway when fire arrives, speed of travel, road obstructions
Shelter Locations (Arrival Points)	Distance to travel, route to travel, end time of evacuation per person
Wildfire History	Areas where wildfires have occurred in the past
Structure Density	Areas of concern for future fire risk
WUI Designator	Areas of concern for future fire risk
Fire Hazard Conditions (rate of spread, flame length, burn probability)	Areas of concern for future fire risk
Key Infrastructure	Areas that may require additional personnel and ingress to protect
Waterway Locations	Access to water for suppression

Inputs	Dataset Use
Near-Road Ignitions	
Hydrant Locations	Access to water for suppression
Safety Locations	Areas that may require additional personnel and ingress to protect
Road characteristics (slope, elevation, complexity, condition)	Areas that may have road congestion and limited access during an evacuation
Main Evacuation Route and Intersections	Areas that may require additional personnel and ingress to protect
Fire Truck Accessibility	Areas in which fire department response may be limited
High-Collision Occurrence	Areas in which traffic collisions occur frequently and may complicate an evacuation
Population (resident, tourist, elderly, children)	Demographics related to ability to evacuate, risk perception, and likelihood to evacuate
Land Use	Demographics related to risk perception and likelihood to evacuate
Income	Demographics related to risk perception and likelihood to evacuate
Vehicle Ownership	Demographics related to ability to evacuate, risk perception, and likelihood to evacuate
Commuting Workers	Demographics related to risk perception and likelihood to evacuate
Commuting and Non-Commuting Students	Demographics related to risk perception and likelihood to evacuate
Gender Distribution	Demographics related to risk perception and likelihood to evacuate
Alert Marin Subscription Rate	Areas which are likely to receive evacuation notices quickly
Linguistic Isolation	Areas in which language barriers may prevent communication of an evacuation mandate
Cellular Coverage Region	Areas in which evacuation alerts cannot be received by cell phone

Table 2. The variables output by each model, the dataset name (see matching name in Data Dictionary for more information), and the potential data usages.

Output	Dataset Use
Fire Arrival Time	Used in communication model by MAZ for risk perception, used in traffic modeling for road obstructions and vehicles on roadway when fire arrives
Number of Times Burned	The sensitivity of the fire behavior to weather and ignition locations; used in background information or preparedness purposes, and mitigation strategies
Ember Generation	Likelihood of spot fires originating from fire scenarios; used in background information, preparedness purposes, and mitigation strategies
Output	**Dataset Use**
Time to Depart	Time it takes for a person to leave their home, used for traffic modeling and road demand over time and starting points; used in additional analysis and background information for education and preparedness purposes
Time of Cognition	Time it takes for a person to be aware of fire threat and evacuation notice, used in evaluation of communication methods, education, and preparedness purposes
Risk Cognition	How and when people perceive fire threat and decide to act; used in evaluation of communication methods, education, and preparedness purposes
Output	**Dataset Use**
Time to Arrive	Time it takes for individuals to reach a safe location (short- or long-term), a shelter, or to exit the county; used to determine time for an area to evacuate
Location of People on Roadway	Location of people on the roadway during an evacuation; used to identify choke points, high roadway saturation, congestion, and people on a roadway when the fire approaches
Road Traffic Volume	Total count of on-road vehicles per traffic node
Average Vehicle Speed	Average speed of on-road vehicles for each road node
Output	**Dataset Use**
Aggregate Difficulty Scores (Fire, Communication, and Roadway)	Aggregate layers of the above model outputs and additional model inputs that provide information on evacuation risk

Appendix A – Data Dictionary for Evacuation Mode

Data Dictionary

Marin County Fuel Model (2022 Impervious Surface Update)

Data Overview

Data origin

Excerpt from Marin County 2020 CWPP (Appendix A): "To develop fuel model data, the two key data inputs are (1) data representing ground vegetation and (2) data that can help to characterize canopy fuels (i.e., the tree canopy). Ground vegetation was available from the Marin County lifeform map, which is a 22-class land use and land cover map of Marin County, reflecting the state of the landscape in summer 2018.46 Data from the new LiDAR survey were used to characterize canopy characteristics in the fuel model data set. The LiDAR data collection was accomplished using a Reigl VQ-1560i sensor system mounted in a Cessna Caravan. Details of the LiDAR data collection can be found in a technical data report (Quantum Spatial, Inc. 2019).

To refine vegetation information for Marin County, vector data that reflected building footprints, waterbodies, and road networks were obtained from MarinMap47 and were used to refine vegetation information for Marin County. The building footprint dataset was produced using 2018 orthoimagery stereo pairs. The waterbody and road datasets were derived from U.S. Census TIGER files, and the road dataset was refined using 2004 orthoimagery."

See Appendix A and Appendix C on the development of the original fuel model data.

Citation

TBD (likely going to cite One Tam for providing raw data and Sonoma Tech. for developing fuel model)

Size

Grid: 455 MB (477,113,364 bytes)

Projection file: 1.71 KB (1,755 bytes)

Data Contents

Scott and Burgan Fire Behavior Fuel Models of the entire area of Marin County

Fire Behavior fuel model attribute data dictionary

Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model

Data Properties

Data Type	Raster (File System Raster)
Data Name	CFM_Impervious_Surface_FM107_to_104.grd CFM_Impervious_Surface_FM107_to_104.prj
Columns and Rows	10647, 11203
Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4241425.73316, 497906.604055, 551141.604055, 4185410.73316)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

Scott and Burgan Fire Behavior Fuel Models is used as input into fire behavior modeling

Appropriate uses of the data product include:

- Input into fire behavior modeling software such as FlamMap
- For cartography and mapping

Inappropriate uses of the data product include:

- Use as a vegetation classification dataset

Data Processing

Fuel model update using impervious surface data from (https://www.arcgis.com/home/item.html?id=dc06dab1a7dc45b286f5bc3d84c48154). We corrected the original fuel model data using the following adjustment:

a. If 91, and if **IS = 0 (i.e., pervious)**,

i. If CC = 0 and CH < 1, 101

If CC = 0 and CH >=1 and <3, 102

ii. If CC < 10% and > 0, 142

iii. If CC >= 10% and < 25%

        1. If CH < 6.1 m, 145
        2. Otherwise, 163
    iv. If CC >= 25% and < 50%
        1. If CH < 6.1 m, 145
        2. Otherwise, 165
    v. If CC >= 50%
        1. If CH < 6.1 m, 147
        2. Otherwise, 165
b. Road buffer using CC; if **IS = 1 (i.e., impervious)**
    i. If CC < 30%, 91
    ii. Otherwise, 181
c. Building footprint using CC; if **IS = 1 (i.e., impervious)**
    i. If CC < 20%, 91,
    ii. If CC >= 20% and < 40%, 181
    iii. Otherwise, 165,

where CC = canopy cover (%), CH = canopy height (m), and IS = impervious (0 = pervious, 1 = impervious). The adjustments from above replaced NDVI in the identification of non-vegetated areas.

We also changed fuel model = 107 to fuel model = 104 to account of unreasonably large rate of spread and flame length in wetland areas.

code: **\\fileserv1\shares\STIShare\ProjectDocs\922021 MWPA Updates to Fire Hazard Maps\Scripts\FuelModel_Update_2022.R**

Data QC

Calculated differences between pre- and post- impervious surface-corrected fuel model:
\\fileserv1\shares\STIShare\ProjectDocs\922021 MWPA Updates to Fire Hazard Maps\Data\CFM_frequency_diff.xlsx
See 2020 Marin CWPP Appendix A and Appendix C for specific QC procedures on original fuel model

Meteorology - Weather & Fuel Moisture

Data Overview

Data origin

Real-Time Mesoscale Analysis (RTMA) is a high spatial resolution (2.5 km) and high temporal resolution (hourly) gridded analysis of surface weather conditions. The primary native quantities that are used for fire modeling include wind speed and direction, relative humidity and temperature, and precipitation. Derived quantities used for fire modeling are dead fuel moisture by size class (1-hr, 10-hr, and 100-hr timelag). The data used in this work were obtained from the National Centers for Environmental Information National Digital Guidance Database (NDGD) and the Iowa State University Environmental Mesonet as cited below.

Citation

https://www.ncei.noaa.gov/products/weather-climate-models/national-digital-guidance-database

https://mtarchive.geol.iastate.edu

Size

Approximately 25 MB

Data Contents

Fire modeling inputs were developed for a rectangular region covering Marin County from the RTMA dataset for the following quantities:

- 20-ft wind speed (mph)
- 20-ft wind direction (degrees, meteorological convention)
- 1-hr dead fuel moisture (%)
- 10-hr dead fuel moisture (%)
- 100-hr dead fuel moisture (%)

These data were "stacked" into multiband GeoTiff rasters, one hour of data per band, to create a series of 24 hour blocks starting on the following date and time (with time in UTC):

- 2017-09-04 19:00
- 2017-10-09 03:00
- 2018-11-08 13:00
- 2019-10-24 03:00
- 2020-08-09 19:00
- 2020-08-21 19:00
- 2020-08-21 20:00
- 2020-09-06 18:00
- 2020-09-06 22:00
- 2020-09-07 01:00
- 2020-10-17 18:00
- 2020-10-17 22:00
- 2020-10-18 01:00
- 2022-05-24 18:00
- 2022-05-24 22:00

- 2022-05-25 01:00
- 2022-06-21 18:00
- 2022-06-21 22:00
- 2022-06-22 01:00

Data Properties

Data Type	GeoTiff
Data Name	ws.tif – 20 ft wind speed (mph) wd.tif – 20 ft wind direction (degrees, meteorological convention) m1.tif – 1-hr fuel moisture (%) m10.tif – 10-hr fuel moisture (%) m100.tif – 100-hr fuel moisture (%)
Columns and Rows	106, 116
Number of Bands	25
Cell Size (X, Y)	600, 600
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(493631.604, 4251210.733, 557231.604, 4181610.733)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

These meteorological data are intended for use as input to fire progression modeling.

Appropriate uses of the data product include:

- Short-term (up to one day) modeling of transient fire progression

Inappropriate uses of the data product include:

- Wind loading studies

Data Processing

Dead fuel moistures were calculated from native quantities using standard procedures from the National Fire Danger Rating System (NFDRS) as described in https://www.srs.fs.usda.gov/pubs/rp/rp_se273.pdf.

Data QC

RTMA documentation is available at https://nomads.ncep.noaa.gov/txt_descriptions/RTMA_doc.shtml

Ignition Region

Data Overview

Data origin

Polygons were drawn manually to constrain ignitions to specific areas of interest that were developed collaboratively and with stakeholder input.

Citation

N/A

Size

17.72 KB

Data Contents

Ignition area polygons were developed for different modeling scenarios, i.e. offshore and onshore/dry sea breeze wind conditions. These scenarios include:

- Fairfax onshore and offshore
- Tamalpais onshore and offshore
- Novato onshore and offshore
- Inverness offshore
- San Rafael - Sorich Park

Data Properties

Data Type	Shapefile Feature Class
Data Name	fairfax_onshore.shp: Fairfax onshore fairfax_offshore.shp: Fairfax offshore tamalpais_onshore.shp: Tamalpais onshore tamalpais_offshore.shp: Tamalpais offshore novato_onshore.shp: Novato onshore novato_offshore.shp: Novato offshore inverness_offshore.shp: Inverness offshore sorich_park.shp: Sorich Park
Extent (top, left, right, bottom)	Varies
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

These data are intended for use in the current study.

Appropriate uses of the data product include:

- Determining ignition locations for short-term fire progression modeling in the project study areas

Inappropriate uses of the data product include:

- Quantification of fire risk outside of the study areas

Data Processing

N/A

Data QC

N/A

Fire Progression

Data Overview

Data origin

The operational fire spread model ELMFIRE (Eulerian Level Set Model of FIRE spread) was used to model fire progression for use in other parts of this study. ELMFIRE is one of the fire models that drives the Pyrecast real-time fire modeling system (https://pyrecast.org). Inputs to this analysis include:

- Marin County fuel model and associated topography
- RTMA meteorological & fuel moisture data
- Ignition area polygons

For each ignition area polygon and wind/weather scenario, 24 hours of fire progression was modeled from 100 randomly-selected ignition locations within each of the ignition area polygons. Modeled fire progression was recorded at 5-minute intervals and saved in ESRI Geodatabase (gdb) format.

Citation

Lautenberger, C., "Wildland Fire Modeling with an Eulerian Level Set Method and Automated Calibration," *Fire Safety Journal* 62: 289-298 (2013).

Size

Approximately 43 GB.

Data Contents

Data are grouped into a directory structure with a naming convention that designates the ignition area and time of ignition used in the fire spread modeling. The following directories are available:

fairfax_20171009_030000	san_rafael_20171009_030000
fairfax_20181108_130000	san_rafael_20181108_130000
fairfax_20191024_030000	san_rafael_20191024_030000
fairfax_20200906_180000	san_rafael_20200906_220000
fairfax_20200906_220000	san_rafael_20200907_010000
fairfax_20201017_180000	san_rafael_20201017_220000
fairfax_20201017_220000	san_rafael_20201018_010000
fairfax_20220524_180000	san_rafael_20220524_220000
fairfax_20220524_220000	san_rafael_20220525_010000
fairfax_20220621_180000	san_rafael_20220621_220000

fairfax_20220621_220000	san_rafael_20220622_010000
inverness_20171009_030000	tamalpais_20171009_030000
inverness_20181108_130000	tamalpais_20181108_130000
inverness_20191024_030000	tamalpais_20191024_030000
inverness_20200906_180000	tamalpais_20200906_220000
inverness_20201017_180000	tamalpais_20200907_010000
inverness_20220524_180000	tamalpais_20201017_220000
inverness_20220621_180000	tamalpais_20201018_010000
	tamalpais_20220524_220000
novato_20171009_030000	tamalpais_20220525_010000
novato_20181108_130000	tamalpais_20220621_220000
novato_20191024_030000	tamalpais_20220622_010000
novato_20200906_220000	
novato_20200907_010000	
novato_20201017_220000	
novato_20201018_010000	
novato_20220524_220000	
novato_20220525_010000	
novato_20220621_220000	
novato_20220622_010000	

Within each directory is a series of files named perim_xxxxxx.gdb where xxxxxx is a sequential ID corresponding to the simulation number, varying from 000001 to 000100. Each simulation number has a different ignition location. The attribute table provides the time after ignition in minutes for each polygon feature in the geodatabase.

Data Properties

Data Type	Shapefile Feature Class
Data Name	perim_xxxxxx.gdb
Extent (top, left, right, bottom)	Varies
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

Fire progression polygons are used as input to traffic and communication modeling.

Appropriate uses of the data product include:

- Traffic and communication modeling

Inappropriate uses of the data product include:

- Generalized risk modeling or analysis

Data Processing

See above

Data QC

Data were reviewed and mapped before passing to traffic and communication teams.

Communication and Decision Model

Data Overview

The communication and decision model is based on (1) demographic data, including population and population clusters to illustrate the number and types of population moving from origin to destination in fire evacuation; (2) geospatial data, employed to visualize roadways, shelter locations, cell tower locations, communication dead zones; (3) communication data, employed to identify types of communication devices used to estimate time of risk cognition in case of fire. Demographic data was drawn from U.S. Census data and aggregated by Fehr & Peers for the Transportation Authority of Marin Demand Model (TAMDM) dataset. The source of geospatial data was the integration of TAMDM (evacuation routes), Zonehaven evacuation arrival locations, Marin County Office of Emergency Services (OES) data (cell phone tower locations), Federal Communication Commission (FCC) data (communication dead zones). Communication data also include American Community Survey 5-Year Data (means of communication).

The time of simulated fire ignition is drawn from the specific scenarios that present particular challenges to the five designated communities, prepared by Sonoma Technology. The simulated fire progression is determined by the wildfire model simulations (ELMFIRE) conducted by Chris Lautenberger. The estimated time of fire ignition serves as the first notification of fire threat (fire watch) communicated to the affected micro analysis zones (MAZs). The wildfire progression simulation provides the fire arrival time to each MAZ, which determines the time of notification for mandatory evacuation (fire warning) for each affected MAZ.

The estimated number of evacuating vehicles is derived from the aggregated TAMDM data that provides the estimated population for each MAZ. For school rush scenarios, US News – Education data are used to identify the number of students enrolled in each school located in the MAZs that are notified by fire watch to estimate the number and location of vehicles that would move towards the school areas to pick up children.

Citation

[1] Transportation Authority of Marin Demand Model(TAMDM) Development Report, September, 2020, **https://tamwebsite900.wpenginepowered.com/wp-content/uploads/2021/01/TAMDM_Development_Report_9-1-2020.pdf**

[2] American Community Survey 5-Year Estimates (2020), **https://data.census.gov**

[3] Alert Marin Update, Marin County Sheriff's Office / OES

[4] FCC Mobile LTE Coverage Map, **https://www.fcc.gov/BroadbandData/MobileMaps/mobile-map** ; **https://fcc.maps.arcgis.com/apps/webappviewer/index.html?id=6c1b2e73d9d749cdb7bc88a0d1bdd25b**

[5] Zonehaven shelter location data. For model runs, the Civic Center and Fairgrounds were used as shelter locations.

Transportation Authority of Marin Demand Model (TAMDM)

Data Overview

Data origin

TAMDM data are used to identify and characterize the populations that are affected by fire and to analyze their movements in traffic patterns. TAMDM data provides the estimated population within each Micro Analysis Zone (MAZ), locations of schools and retirement facilities, and other population clusters. Demographic data for the residents and employees within Marin County provide information on the estimated number of vehicles that are available for trips from origin to destination.

Citation

[1] Transportation Authority of Marin Demand Model (TAMDM) Development Report, September, 2020, **https://tamwebsite900.wpenginepowered.com/wp-content/uploads/2021/01/TAMDM_Development_Report_9-1-2020.pdf**

Size

Details in Data Properties tables

Data Contents

Marin County Population

School Locations

Marin Resident-Worker Location Data

Marin Person Location by time of day Data

Data Properties

Population

Data Type	Shapefile Feature Class
Data Name	TAMDM_MAZdata.shp
Projection	NAD_1983_UTM_Zone_10N
Size	3 MB
Data Source	TAMDM MAZ boundary dataset with joining TAMDM tables

School Location

Data Type	Shapefile Feature Class
Data Name	School_Loc_TAMDM_MAZdata.shp
Projection	NAD_1983_UTM_Zone_10N
Size	12 KB
Data Source	School locations from MarinMap with joined with TAMDM MAZ location data

Resident-Worker Location

Data Type	table (comma-separated values)
Data Name	Resident_Data.csv
Size	101.1 MB
Columns and Rows	20/785163
Description	Records of residents and employees, including information

	on age, gender, home location, work location, and school location in Marin County.

Person Location by Time of Day

Data Type	table (comma-separated values)
Data Name	Person_Data.csv
Size	907 KB
Columns and Rows	20/1419
Description	The number of persons in each MAZ by time of day.

Data Use

TAMDM data is used to identify the populations that are impacted by the fire progression modeling output. The distance between school locations and each MAZ are calculated for fire scenarios where the fire ignites around the time of school dismissal to simulate the traffic flow of school dismissal. The resident and person location data are used to estimate the number of people within MAZs in Marin County Resident and person location data are linked to the traffic model to estimate the distribution of vehicles on county roads by day of week and time of day (see the Traffic Model Data Dictionary entry for details about the distribution of resident data)

Data Processing

In "TAMDM_MAZdata.shp", the MAZ ID field from the TAMDM data is named as "New_MAZ". In "School_Loc_TAMDM_MAZdata.shp", MAZ ID is named as "New_MAZ", presenting MAZ boundary in which schools are located.

The school locations shapefile was spatially joined to the MAZ boundaries to identify the unique MAZ boundary IDs that overlap with the schools.

Data QC

N/A

Zonehaven Shelter Locations

Data Overview

Data origin

The data consist of a variety of locations (parking lots, parks, schools, etc.) that local emergency managers (local police departments, fire departments, California Highway Patrol) have identified as potential locations where people can go in the case of an emergency evacuation. The Office of Emergency Services partnered with Zonehaven to collect this data from these local emergency managers. According to Zonehaven data, there are total of 32 “arrival points” that have potential to be shelters.

Citation

[1] Zonehaven shelter location data

Data Contents

Zonehaven shelter locations

Data Properties

Shelter Locations

Data Type	Shapefile Feature Class
Data Name	arrival_points_UTM10_MAZ.shp
Size	31.8 KB
Data Source	Zonehaven shelter location data

Data Use

Zonehaven data was used to identify potential shelters to which people could evacuate in fire and are considered key infrastructure. The MAZ ID of the shelter locations are used as destinations for evacuees in traffic model.
Additionally, safety locations are used to develop fixed risk variable layers within the Fire and Roadway Difficulty Scores (see section 5.1 and 5.2 of the Tech 4 Technical Report).

Data Processing

First, from the Zonehaven data, 32 "arrival points" were chosen in Marin County. The arrival points included community center, parks, malls, auditoriums, schools etc. Then, the locations were processed to shapefiles and were visualized in maps. Out of those potential shelters, Marin Civic Center and Marin County Fair Grounds were designated as shelters considering the current conditions and location. These two locations are both located within MAZ ID 5742, set as destination for evacuees departing from their respective origins.

Data QC

N/A

Office of Emergency Services Data

Data Overview

Data origin

The Marin County Office of Emergency Services (OES) data provides the number of Alert Marin Subscribers per ZIP code. The number of Alert Marin Subscribers per ZIP code provide information about the number of people who could be notified of fire through the County-managed alert service using various means of communication including cell phone, landline, email address, and Everbridge mobile app.

Citation

[1] Alert Marin Update, Marin County Sheriff's Office / OES

Size

Details in Data Properties tables

Data Contents

The Number of Alert Marin Subscribers

Data Properties

Number of Alert Marin Subscribers

Data Type	pdf

Data Name	MWPA_211216_AlertMarin.pdf
Size	1 MB
Data Source	Alert Marin Update, Marin County Sheriff's Office / OES
Description	Provides data about percentages of households that have at least one person registered in AlertMarin.

Data Type	Shapefile Feature Class
Data Name	Zip_Code_UTM10.shp
Projection	NAD_1983_UTM_Zone_10N
Size	207 KB
Data Source	Alert Marin Update, Marin County Sheriff's Office / OES
Description	A shapefile of ZIP code boundaries in Marin County with information on the number of households subscribed to Alert Marin and the percent of total households registered to Alert Marin.

Data Use

The number/percentage of AlertMarin subscribers is used in considering the ratio of people being notified of fire using different communication devices.

Data QC

N/A

Federal Communication Commission Data

Data Overview

Data origin

From Federal Communications Commission (FCC) website, cell phone tower locations and cell phone and cell data reception coverage data were collected. The data includes the nation's four largest mobile carriers (AT&T, T-Mobile, UScellular, and Verizon). In the map, separate layers for each carrier's broadband and voice coverage are presented.

Citation

[1] FCC Mobile LTE Coverage Map, https://www.fcc.gov/BroadbandData/MobileMaps/mobile-map ; https://fcc.maps.arcgis.com/apps/webappviewer/index.html?id=6c1b2e73d9d749cdb7bc88a0d1bdd25b

Size

Cell phone and cell data coverage: 532 KB

Cell phone tower locations: 23.6 KB

Data Contents

Cell phone and data reception coverage: https://us-fcc.app.box.com/s/f220avmxeun345o6gzr7rwcnp1wslocf

Cell phone tower locations: https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::cellular-towers/aboutData Properties

Cell phone tower locations

Data Type	Shapefile Feature Class
Data Name	CellTowers.shp
Extent (top, left, right, bottom)	(4244520.57624223, 498156.31368064, 544162.13246657, 4189404.61345941)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Cell phone and data reception coverage

Data Type	Shapefile Feature Class
Data Name	All_Data_Dissolved.shp / All_Voice_Dissolved.shp
Size	532 KB
XY Coordinate System	NAD_1983_UTM_Zone_10N
Data Source	FCC Mobile LTE Coverage Map (AT&T, T-Mobile, UScellular, Verizon)

Data Use

The FCC data on cell coverage – voice and data – is used to identify the dead zones of cell communication. The dead zones could be interpreted as potential areas of communication breakage, which need back up communication measures.

Data Processing

The data and voice coverage boundaries for AT&T, Verizon, and T-Mobile were combined to produce boundaries that represent the total data coverage and total voice coverage of Marin County. USCellular data and voice coverage boundaries did not add any areas of coverage not covered by the AT&T, Verizon, and T-Mobile and were left out of the processing. The cell phone tower was clipped to include only the cell phone towers in and around Marin County.

Data QC

N/A

U.S. News - Education Data

Data Overview

Data origin

The US News – Education data provides data on the number of students for schools within Marin County. Schools located within or near the areas affected by fire (see the TAMDM Data entry) are designated as destinations for parents or guardians who would pick up kids after school is dismissed.

Citation

[1] https://www.usnews.com/education/k12/search

Data Contents

The number of students per school

Data Properties

Data Type	html (webpage)

Data Use

The number of students is used to infer the number of parents' or guardians' vehicles moving from their home MAZ origin to the immediate destination – the respective schools. The number of additional vehicles contributed by the parents or guardians provides estimates about the number of children who may need special assistance in evacuation and in shelters when they arrive.

Traffic Evacuation Model

Data Overview

Data origin

The traffic evacuation model is based on (1) Traffic network of Marin County; (2) normal traffic OD data, employed to simulate the normal traffic; (2) Evacuation OD data, employed to simulate the evacuation traffic. The traffic network of Marin County is drawn from OpenStreet Map. The normal traffic OD data and evacuation OD data are drawn from the TAMDM data that provides the estimated daily travel data and evacuation travel data. After we collected this data, we ran the traffic simulation model and obtained the following outputs: the hourly volume and speed of each road.

Size

Hourly volume and speed of each road: 5.1 MB (5,063,375 bytes)

Data Contents

Hourly volume and speed of each road

Road Nodes	
Attribute	Description
link_id	the identity of each road link
Length	The road length [m]
volume	The number of vehicles passing through this link during this hour
speed	The average speed of vehicles in this link during this hour
geometry	The location of the road link

Data Properties

Data Type	csv
Data Name	link_stats.csv
Columns and Rows	40210, 5

Data Use

This is the model output.

Data Processing

We run the spatial-queue-agent-based simulation model (https://github.com/cb-cities/spatial_queue) with the above data as input. Following that, the output is obtained.

OpenStreetMap

Data Overview

Data origin

OpenStreetMap is an open-sourced geographic database that is maintained by a community of volunteers and is used in a variety of mapping applications throughout the world. OpenStreetMap contains points of road intersections (road nodes) and stretches between intersections (road links).

Citation

[1] OpenStreetMap. www.openstreetmap.org

Size

Road links: 8.8 MB (8,753,882 bytes)

Road nodes: 636 KB (635,872 bytes)

Data Contents

Road network of Marin County

Road Nodes	
Attribute	Description
node_id	the identity of each road intersection
lon	the longitude of the road intersection
lat	the latitude of the road intersection

Road Links	
Attribute	Description
start_node_id	the upstream intersection of the road link
end_node_id	the downstream intersection of the road link
length	The length of the road link [meter]
lanes	The number of lanes on this road link
link_type	The class of this road [motorway, primary, secondary, tertiary, residential, service]

maxmph	The speed limit on this road link [miles per hour]
geometry	The coordinates of this road link

Data Properties

Data Type	csv
Data Name	node.csv
Columns and Rows	17858, 3

Data Type	Shapefile Feature Class
Data Name	Marin_Network_Links.shp
Columns and Rows	40210, 9
XY Coordinate System	NAD_1983_UTM_Zone_10N

Data Use

The OpenStreetMap road network is the foundational data layer used in traffic evacuation modeling and the Roadway Difficulty Score.

Data Processing

The road nodes and links were clipped to the Marin County boundary. For the Roadway Difficulty Score, a 50 meter buffer around each road segment is developed to calculate and assign fixed and variable risk scores.

Data QC

N/A

The Fire Location and Arrival Times

Data Overview

Data origin

The fire location and arrival times (i.e., time after ignition) are outputs from the fire spread modeling (ELMFIRE). The fire arrival times are intersected with road links and MAZ boundaries to determine the time after ignition that the fire reaches a given road link and MAZ.

Citation

[1] Fire Modeling Simulation Results

Size

Details in Data Properties tables

Data Contents

Fire Location and Fire Arrival Times by MAZ

Data Properties

Fairfax

Data Type	csv
Data Name	MAZ_Zones20220621_18.csv (onshore) MAZ_Zones20171009.csv (offshore)
Size	34 KB; 21 KB
Columns and Rows	5/1419; 4/1419
Data Source	Fire Modeling Simulation

Novato

Data Type	csv
Data Name	MAZ_Zones20200906_2200.csv (onshore); MAZ_Zones20191024_03.csv (offshore)
Size	37 KB; 37 KB
Columns and Rows	5/1419; 5/1419
Data Source	Fire Modeling Simulation

San Rafael

Data Type	csv
Data Name	MAZ_Zones20200907_01.csv (onshore); MAZ_Zones20181108_13.csv (offshore)
Size	37KB; 37KB
Columns and Rows	5/1419; 5/1419
Data Source	Fire Modeling Simulation

Tamalpais

Data Type	csv
Data Name	MAZ_Zones20220621_22.csv (onshore); MAZ_Zones20171009_03.csv (offshore)
Size	37KB; 37KB
Columns and Rows	5/1419; 5/1419
Data Source	Fire Modeling Simulation

Inverness

Data Type	csv
Data Name	MAZ_Zones20200906_18.csv (onshore); MAZ_Zones20170904_19.csv (offshore)
Size	36KB; 36KB
Columns and Rows	5/1419; 5/1419
Data Source	Fire Modeling Simulation

Data Use

Fire arrival times are intersected with the MAZs to determine the time after ignition that the fire boundaries interact with the MAZ. Integrating the fire location and arrival times determines the evacuation departure times for the population within the affected MAZs. First, the fire ignition time is defined as the time that the Marin County Fire Department notifies residents in the affected MAZs of fire threat (fire watch), indicating that they are at risk and to prepare for possible evacuation. The fire watch notification is a "one-to-many" communication (i.e., one sender generates and disseminates information to multiple receivers) with no certainty that all residents of the affected MAZs have received the notice (i.e., risk cognition). Second, the time of fire arrival at the MAZs under threat determines the time of mandatory evacuation order (fire warning). Again, this is a one-to-many communication with no guarantee that all persons notified have received the warning and will act on it.

Data Processing

The minimum time of fire arrival (see the Fire Progression entry) at each road link is calculated for all 100 random ignition fires for each meteorological scenario. Out of the 100 random ignition fires, one fire progression is selected as the fire used throughout the modeling process. The selected fire is based on the number of road links that interact with each fire; the fire that interacts with the greatest number of road links is selected. The selected fire is used to determine the minimum time of arrival at each affected MAZ. From the original time of fire arrival data (csv file), the rows that have minimum and maximum times of fire arrival entries were filtered and rearranged into one excel file classified by case areas in separate sheets.

It is assumed that “fire watch” is sent out immediately after fire ignition, and then depending on the types of communication devices that people use, the times of mandatory evacuation notification and times of departure are determined. The “fire warning”, or mandatory order for people to evacuate, is assumed to be sent out 10 hours before minimum time of fire arrival since they have high risk of being affected by fire after 10 hours. Again, it is assumed that people are notified of a mandatory evacuation order through Alert Marin that uses various communication devices, which in turn affect their departure time for evacuation.

Data Output Description

Row Label	Description
vehs	Number of evacuating vehicles
o_maz	MAZ ID of the ORIGIN of the evacuating vehicles
d_maz	MAZ ID of the DESTINATION of the evacuating vehicles
time	Time of departure for evacuating vehicles

Normal Travel Demand

Data Overview

Data origin

The normal travel demand was available from TAMDM data, provided by Fehr & Peer. With this data, the daily normal traffic can be simulated.

Citation

[1] TAMDM data. www.fehrandpeers.com

Size

Travel demand: 392.7 MB (392,702,496 bytes)

Data Contents

TAMDM data dictionary (https://tamwebsite900.wpenginepowered.com/wp-content/uploads/2021/01/TAMDM_Users_Guide_9-17-2020-Final.pdf)

Data Properties

Data Type	Xlsx
Data Name	background_ods_day_for_Marin_TAMDM_data.csv
Columns and Rows	888960, 6

Data Use

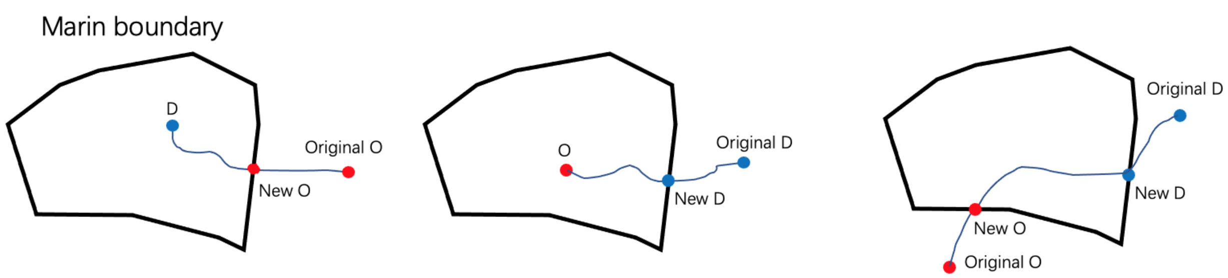
TAMDM data is used as input into traffic evacuation model.

Appropriate uses of the data product include:

- Normal daily traffic
- Travel behavior analysis

Data Processing

The raw OD data provided by TAMDM is the zone-level OD data. It means that we only know the zones which each trip originates from/heads to. We converted the zone-level OD data into node-level OD data through assigning the origin/destination of each trip to the nodes within the origin/destination zone randomly. Besides, we also adjusted the origins/destinations of trips which were originally outside Marin County to the borders of Marin County and adjusted the departure times of trips whose origins were adjusted to the borders of Marin County. Here, we give an illustrative example. From (a), we can see that if Origin is outside the Marin County, then we adjust the origin to the border of Marin County and adjust the departure time correspondingly. If the destination is outside the Marin County, we just adjusted its destination. If Origin and destination are both outside, we adjust them at the same time.



(a) O is outside (b) D is outside (c) O/D are outside

Data QC

N/A

The Distribution of Residents of Marin County

Data Overview

Data origin

TAMDM data is used to identify the distribution of residents within Marin County. The data includes persons age/gender, home location, work location for residents and employees. This data also provides the number of vehicles available to each person based on their household auto ownership from census data. In addition, TAMDM data provides person location by the time of day which reflects the population difference by day and night.

Citation

[1] Transportation Authority of Marin Demand Model (TAMDM) Development Report, September, 2020, https://tamwebsite900.wpenginepowered.com/wp-content/uploads/2021/01/TAMDM_Development_Report_9-1-2020.pdf

Size

Details in Data Properties tables

Data Contents

Resident and person location data

Data Properties

Resident-Worker Location Data

Data Type	csv
Data Name	Resident_Data.csv
Size	91MB
Data Source	TAMDM_2019_Data_for_Marin_County
Columns and Rows	21/785,163

Person Location by Time of Day

Data Type	csv
Data Name	Person_Data.csv
Size	907KB
Data Source	TAMDM_2019_Data_for_Marin_County
Columns and Rows	20/1419

Data Use

The resident and person location data are employed to characterize the population by their demographics and identify their location by time of day.

The “HomeMGRA” field corresponds to the “New_MAZ” in “TAMDM_MAZdata.shp.” (Resident_Data.csv). The “MAZ” field corresponds to the “New_MAZ” in “TAMDM_MAZdata.shp”(Person_Data.csv).

Data Processing

N/A

Marin County Wildland Fire History

Data Overview

Data origin

The data was produced by The California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP).

Excerpt from FRAP's GIS Data Portal: "This is a multi-agency statewide database of fire history. For CAL FIRE, timber fires 10 acres or greater, brush fires 30 acres and greater, and grass fires 300 acres or greater are included. For the USFS, there is a 10-acre minimum for fires since 1950."

The data was last updated in October 2022.

Citation

TBD

Size

840 kB

Data Contents

Wildland fire history polygons over Marin County. The dataset contains fire perimeters from 1923 – present.

Data Properties

Data Type	Shapefile Feature Class
Data Name	Marin_County_WildFire_History.shp
Extent (top, left, right, bottom)	(4237631.543800, 498297.033200, 550797.113700, 4186005.299400)

XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

TBD

Data Processing

Original data containing wildland fire perimeters encompassing all of California was projected from NAD_1983_California_Teale_Albers to NAD_1983_UTM_Zone10N, then clipped using the shapefile delineating Marin County.

Data QC

N/A

Marin County Wildland Urban Interface (WUI)

Data Overview

Data origin

The data was produced by Marin County and is hosted on Marin GeoHub

Excerpt from Marin GeoHub and data description: "The Urban Wildland Interface (or Wildland urban Interface: WUI) represents areas where homes/structures are in close proximity to or intermixed with wildland/open space areas."

The data was last updated on November 10, 2020.

Citation

TBD

Size

134 kB

Data Contents

The WUI boundary in Marin County.

Data Properties

Data Type	Shapefile Feature Class
Data Name	urban_wildland_interface_UTM10.shp
Extent (top, left, right, bottom)	(4235077.6129453, 502434.530726262, 549399.260368845, 4188409.92224141)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

TBD

Data Processing

Original data containing the WUI was projected from NAD_1983_HARN_StatePlane_California_III_FIPS_0403_Feet to NAD_1983_UTM_Zone10N

Data QC

N/A

Tourism Data

Data Overview

Data origin

The boundaries for the tourism data are defined by the MAZ boundaries. Tourism data for the federally owned parks are from the National Park Service statistics website.

Citation

TBD

Size

3.03 MB

Data Contents

Estimated tourism population per MAZ boundary. The tourism population represents a hypothetical population on a given weekend day.

Data Properties

Data Type	Shapefile Feature Class
Data Name	MAZ_Tourism_JoinCount.shp
Extent (top, left, right, bottom)	(4241460.5403, 497876.0432, 4185388.5141, 551141.2303)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

The tourism population is added to the general population per MAZ to estimate the effect additional persons would have on traffic during the "weekend" evacuation scenario.

Data Processing

For federally owned lands, tourism statistics (i.e., total visitor county per month) were collected for Muir Woods National Monument, Point Reyes National Seashore, and the Golden Gate National Recreation Area (Marin Headlands Unit). Half of the monthly tourist population were assumed to have visited each area over the weekend. Half of the weekend tourist population were assumed to have visited on either weekend day (i.e., Saturday or Sunday). The number of weekend day visitors was divided by 4 (i.e., the number of weekends in a month) to estimate the approximate number of visitors on a single weekend day for the entire month. For federally owned lands that span multiple MAZ boundaries, the number of visitors allocated to each MAZ that falls within/intersects the federally owned land boundary is proportional to the number of road links that intersect the MAZ boundary. The data processing described above implies that a greater number of tourists tend to visit MAZs that overlap federally owned lands with greater vehicle access than MAZs that have less vehicle access (i.e., are more remote). For federally owned lands that roughly span a single MAZ (e.g., Muir Woods National Monument), the visitor count is added to the total population of the MAZ.

Data QC

N/A

Vegetation Cover (%), Slope (degrees), and Elevation (meters)

Data Overview

Data origin

Excerpt from Marin County 2020 CWPP (Appendix A.3 Image Processing): "LiDAR and NAIP imagery for Marin County were combined to provide information about vegetation cover and topography across the county. All rasters produced for use in this project were aligned to the datasets derived from raw LiDAR point clouds, projected to UTM zone 10N using the NAD83 datum with a cell size of 5 meters. LiDAR tiles were combined and processed using standard ArcGIS geoprocessing tools to derive bare earth elevation, slope, aspect, vegetation height, and vegetation percent cover. Vegetation height and vegetation cover on the 5 m grid were calculated using the internal point classification, which groups vegetation and building returns together."

See Appendix A and Appendix C on the development of the Vegetation Cover, Slope, and Elevation datasets.

Citation

TBD (likely going to cite One Tam for providing raw data and Sonoma Tech. for developing fuel model)

Size

Vegetation Cover: 521 MB

Slope: 504 MB

Elevation: 504 MB

Data Contents

Percent vegetation cover in percent, slope in degrees, and elevation in meters

Data Properties

Vegetation Cover (%)

Data Type	Raster (File System Raster)

Data Name	vegcov_per
Columns and Rows	11310, 11849
Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4243470.73316, 495826.604055, 552376.604055, 4184225.73316)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Slope (degrees)

Data Type	Raster (File System Raster)
Data Name	slope
Columns and Rows	10801, 12001
Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4244000.73316, 497496.604055, 551501.604055, 4183995.73316)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Elevation (meters)

Data Type	Raster (File System Raster)
Data Name	elevation
Columns and Rows	10801, 12001
Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4244000.73316, 497496.604055, 551501.604055, 4183995.73316)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

Vegetation cover was used in the processing of the fuel model layer (see Marin County Fuel Model (2022 Impervious Surface Update) for details. Vegetation cover, slope, and elevation are used as input into fire behavior modeling.

Additionally, elevation and vegetation percent cover are used to develop fixed risk variable layers within the Roadway Difficulty Score (see section 5.2 of the Tech 4 Technical Report).

Data Processing

The processing of each dataset is described in detail in the 2020 Marin County CWPP.

Data QC

See 2020 Marin CWPP Appendix A and Appendix C for specific QC procedures.

Canopy Bulk Density (lbs/ft^3)

Data Overview

Data origin

Excerpt from Marin County 2020 CWPP (Appendix A.6 Landscape File Creation): "In lieu of actual field measurements of canopy fuels in Marin County, canopy bulk density was estimated for pixels with a timber-understory or a timber litter fuel type model using plot data collected for ponderosa pine/Douglas-fir and Sierra Nevada Mixed Conifer forest types in the Interior West (Scott and Reinhardt, 2005). For each fuel model and canopy cover bin, a canopy bulk density value was assigned."

See Appendix A and Appendix C on the development of the Canopy Bulk Density dataset.

Citation

TBD (likely going to cite One Tam for providing raw data and Sonoma Tech. for developing fuel model)

Size

521 MB

Data Contents

Canopy bulk density in lbs/ft^3

Data Properties

Canopy Bulk Density (lbs/ft^3)

Data Type	Raster (File System Raster)
Data Name	cbd_lbs
Columns and Rows	10801, 12001
Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4244000.73316, 497496.604055, 551501.604055, 4183995.73316)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

Crown bulk density is used as input into fire behavior modeling.

Data Processing

The processing of each dataset is described in detail in the 2020 Marin County CWPP.

Data QC

See 2020 Marin CWPP Appendix A and Appendix C for specific QC procedures.

Flame Length (ft), Rate of Spread (ft/min), and Burn Probability

Data Overview

Data origin

Flame length, rate of spread, and burn probability raster layers are outputs from the fire behavior modeling software FlamMap. These layers were created as part of a 2022 update to the 2020 Marin County CWPP fire behavior modeling analysis. All layers represent fire behavior conditions during an "extreme" summer meteorological scenario (i.e., 97th percentile of North American Model (NAM) true wind speed using data from July – October of 2016 – 2021).

Citation

TBD

Size

Flame Length: 455 MB

Rate of Spread: 455 MB

Burn Probability: 12.63 MB

Data Contents

Flame length (ft), rate of spread (ft/min), and burn probability for an extreme summer meteorological scenario.

Data Properties

Flame Length (ft)

Data Type	Raster (File System Raster)
Data Name	FlameLength_final.tif
Columns and Rows	10647, 11203
Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4241425, 497906, 551141, 4185410)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Rate of Spread (ft/min)

Data Type	Raster (File System Raster)
Data Name	ROS_ft_min_final.tif
Columns and Rows	10647, 11203

Number of Bands	1
Cell Size (X, Y)	5, 5
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4241425, 497906, 551141, 4185410)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Burn Probability

Data Type	Raster (File System Raster)
Data Name	Burn_Probability_final.tif
Columns and Rows	1774, 1867
Number of Bands	1
Cell Size (X, Y)	30, 30
Pixel Type	Floating point
Pixel Depth	32 Bit
Extent (top, left, right, bottom)	(4241425, 497906, 551126, 4185415)
XY Coordinate System	NAD_1983_UTM_Zone_10N
Linear Unit	Meter (1.0)

Data Use

Flame length, rate of spread, and burn probability were used in the aggregate evacuation difficulty analysis, specifically in the Fire and Roadway Difficulty Scores.

Data Processing

Flame length, rate of spread, and burn probability are outputs of the fire behavior modeling software FlamMap. FlamMap uses a landscape file consisting of the Marin County Fuel Model (2022 Impervious Surface Update), elevation, slope, percent vegetation cover, vegetation height, crown bulk density, and crown base height (see entries for details) and fire behavior algorithms to calculate the flame length, rate of spread, and burn probability for every pixel in the study area (i.e., Marin County).

Data QC

Statistics of the 2022 updated versions of flame length and rate of spread raster layers were compared to statistics of the 2020 original versions of flame length and rate of spread used in the 2020 Marin County CWPP.

Key Infrastructure Locations

Data Overview

Data origin

The location(s) of airports, county facilities, fire stations, hydrants, law enforcement buildings, libraries, medical facilities, and schools in Marin County data were produced and hosted by **MarinMap**. The location of cell phone towers were extracted from the FCC website (see the *Federal Communication Commission Data* entry for more details). The location of substations, transmission lines, and power plants were extracted from the California Electric Commission **GIS Open Data website**.

Citation

TBD

Size

Airports: 170 KB

County Facility: 33.2 KB

Fire Stations: 197 KB

Hydrant Locations: 1.02 KB

Law Enforcement Facilities: 25.4 KB

Libraries: 190 KB

Medical Facilities: 34.8 KB

Schools: 232 KB

Substations: 1.09 MB

Transmission Lines: 8.95 MB

Power Plants: 2.12 MB

Data Contents

The key infrastructure locations contain the location(s) of airports, bus routes, county facilities, fire stations, hydrants, law enforcement buildings, libraries, medical facilities, schools, and cell phone towers in Marin County, and electric utility infrastructure in California.

Data Properties

Airport

Data Type	Shapefile Feature Class
Data Name	airport_UTM10.shp
Extent (top, left, right, bottom)	(4221342.22195007, 539081.133859755, 541709.074813341, 4207645.60340128)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Count Facility

Data Type	Shapefile Feature Class
Data Name	county_facility_UTM10.shp
Extent (top, left, right, bottom)	(4233185.67016342, 507855.276188245, 548014.519123593, 4191796.33823566)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Fire Stations

Data Type	Shapefile Feature Class
Data Name	fire_station_UTM10.shp
Extent (top, left, right, bottom)	(4233160.71275861, 507860.332413415, 547760.635115883, 4187363.40078983)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Hydrant Locations

Data Type	Shapefile Feature Class
Data Name	hydrant_UTM10.shp

Extent (top, left, right, bottom)	(4239326.99016921, 502662.654565668, 549078.622283996, 4188739.76344089)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Law Enforcement Facilities

Data Type	Shapefile Feature Class
Data Name	law_enforcement_UTM.shp
Extent (top, left, right, bottom)	(4217720.99764285, 516835.217682911, 547007.345119861, 4190453.81783468)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Libraries

Data Type	Shapefile Feature Class
Data Name	library_UTM10.shp
Extent (top, left, right, bottom)	(4217794.13687725, 512861.846197754, 547364.15107929, 4190373.02756223)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Medical Facilities

Data Type	Shapefile Feature Class
Data Name	medical_facility_UTM10.shp
Extent (top, left, right, bottom)	(4219424.44452993, 516971.197869377, 543907.972386979, 4191830.46567001)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Schools

Data Type	Shapefile Feature Class
Data Name	school_UTM10.shp
Extent (top, left, right, bottom)	(4233291.9187653, 508621.559743322, 547066.423161061, 4190780.62485263)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Substations

Data Type	Shapefile Feature Class
Data Name	CA_Substations_Final_UTM10.shp
Extent (top, left, right, bottom)	(4659896.75371725, 397617.177456263, 1316461.2436037, 3618528.81574477)

XY Coordinate System	NAD_1983_UTM_Zone_10N

Transmission Lines

Data Type	Shapefile Feature Class
Data Name	Transmission_Line_UTM10.shp
Extent (top, left, right, bottom)	(4659837.18585441, 397591.788087691, 1427706.96015015, 3614247.79329481)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Power Plants

Data Type	Shapefile Feature Class
Data Name	California_Power_Plants_UTM10.shp
Extent (top, left, right, bottom)	(4648373.83650388, 397957.832681844, 1448417.62981506, 3617349.11930432)
XY Coordinate System	NAD_1983_UTM_Zone_10N

Data Use

Key infrastructure layers were used in the aggregate evacuation difficulty analysis, specifically as a fixed risk layer (excluding hydrant locations) in the Roadway Difficulty Score. Hydrant locations were also used in the aggregate evacuation difficulty analysis as a variable risk layer.

Data Processing

Data from MarinMap were projected from NAD_1983_HARN_StatePlane_California_III_FIPS_0403_Feet to NAD_1983_UTM_Zone_10N. See the *Federal Communication Commission Data* for more details on cell phone tower location data processing. Data from the California Electric Commission were projected from WGS_1984_Web_Mercator_Auxiliary_Sphere to NAD_1983_UTM_Zone_10N.

Data QC

N/A

Historical Traffic Collision Locations

Data Overview

Data origin

The Transportation Injury Mapping System (TIMS) has been developed over the past ten-plus years by SafeTREC to provide quick, easy and free access to California crash data, the Statewide Integrated Traffic Records System (SWITRS), that has been geo-coded by SafeTREC to make it easy to map crashes.

Citation

Transportation Injury Mapping System (TIMS), Safe Transportation Research and Education Center, University of California, Berkeley. 2023

Size

CrashLocationData_2011_2020_UTM10.shp: 110MB

Data Contents

Geographic location of vehicle related crashes within Marin County from January 2011 to December, 2020.

Data Properties

CrashLocationData_2011_2020_UTM10.shp

Data Type	Point
Data Name	CrashLocationData_2011_2020_UTM10
XY Coordinate System	NAD_1983_UTM_Zone_10N
Field attributes definitions can be found on the TIMS website	https://tims.berkeley.edu/tools/query/index.php?clear=true

Data Use

Crash data locations were used in the aggregate evacuation difficulty analysis, specifically as a variable risk layer in the Roadway Difficulty Score.

Data Processing

Data query for crash locations from 2011 to 2020 for Marin County. Latitude and longitude fields were mapped within the GIS to create a point spatial layer.

Data QC

N/A

Pavement Condition Index (PCI)

Data Overview

Data origin

PCI data were hosted and produced by Vital Signs.

Citation

TBD

Size

geo_export_99adafc3-6f22-4f2d-8814-f6908e025866.shp: 258 MB

Data Contents

Roadways with pavement condition categories (Excellent/Very Good, Good/Fair, At Risk, Poor/Failed)

Data Properties

Data Type	Shapefile Feature Class
Data Name	geo_export_99adafc3-6f22-4f2d-8814-f6908e025866.shp
Extent (top, left, right, bottom)	(38.8564397005941, -123.431492, -121.477649, 36.957649)
XY Coordinate System	WGS84(DD)

Data Use

PCI data were used in the aggregate evacuation difficulty analysis.

Data Processing

None

Data QC

N/A

Appendix B - Data Sources Identified in the Literature for Evacuation Modeling

For each variable identified, a brief description of what the variable provides information for, in what context the data is used (as a model input or a base map), and if the data is readily available. Data availability is grouped into several categories (yes, limited, can calculate, estimated, and assumption). Limited indicates data is available, however, some information may be missing or uncertain for specific areas. Estimated and can-calculate indicate we can use available data to model or derive the values needed. Assumptions are variables which are stochastic during an evacuation that are prescribed during model simulations.

Variable	Information	Use	Available
Fuel bed Characteristics	Fire behavior, smoke emissions for visibility impairment	Fire Model	Yes
Vegetation Characteristics	Likelihood for an area to burn at high severity and fire spread	Base Maps, Fire Model	Yes
Land Cover and Change	Fire spread, structure density, debris potential (roadblocks due to trees close to roadways), terrain and elevation impacts	Base Maps	Yes
Fuel Moisture	Likelihood for an area to burn at high severity and fire spread, likelihood of ignition	Base Maps, Fire Model	Yes
Soil Moisture	Likelihood for an area to burn at high severity and fire spread	Base Maps	Yes
Burn Probability	Likelihood for an area to experience a wildfire or reach extreme conditions given an ignition	Base Maps, Fire Model	Yes
Fire Intensity	Likelihood to destroy structures and pose danger to z-shelters or vehicles	Fire Model	Can Calculate
Fire Ember Production and Spread	Likelihood to destroy structures, likelihood to spread in unpredictable manor	Fire Model	Can Calculate
Meteorology	For use in fire spread	Fire Model	Yes
Hot-Dry-Windy-Index	Likelihood fire will exceed resources available to contain, increased risk of spread or multi-day evacuation	Base Maps	Can Calculate
Fire History	Previous fire risks and burn areas for fire spread and evacuation	Base Maps	Yes
Fire Spread	To determine the risk zone and communities affected	Fire Model	Yes
Home Age	To determine risk of structures to ignition	Base Maps	Yes
Home Hardening	To determine risk of structure to ignition and inform resident decision to stay/go	Base Maps	Limited
Zoning	To determine risk of structure to ignition, housing density, and population at various time-of-day	Base Maps	Yes
Distance to Fire Perimeter	Time of resident awareness and urgency	C&D Model, Traffic Model	Yes
Phone Availability	Time of resident awareness	C&D Model	Yes
Internet Availability	Time of resident awareness and additional information seeking capability	C&D Model	Yes
Radio Availability	Time of resident awareness	C&D Model	Estimated
Enrollment in AlertMarin	Time of resident awareness	C&D Model	Yes
Unsheltered Population	Time and method of resident awareness	C&D Model	Yes
Visitors (Number of Persons)	Time and method of awareness	C&D Model	Estimated
Methods of Alerts	Time of awareness, number of persons reached	C&D Model	Estimated

Variable	Information	Use	Available
Quality and Number of Alerts	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating (ordered, shadow), time to depart, time of awareness	C&D Model	Estimated
Length of Residence	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating	Base Maps	Estimated
Income	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating, time to depart, distance to final destination	Base Maps	Yes
Ethnicity	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating, time to depart, distance to final destination	Base Maps	Yes
Age	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating, time to depart, distance to final destination	Base Maps, C&D Model	Yes
Number of Persons	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating, time to depart, distance to final destination, number of persons per vehicle, number of seats available in car for neighbors	Base Maps, C&D Model	Yes
Number of Vehicles	Number of vehicles on roadway, congestions, method of evacuation	Base Maps, C&D Model, Traffic Model	Yes
Agricultural Land Classifications	Area with livestock to evaluate resident decision to stay or go	Base Maps	Yes
Household Pets	Likelihood to evacuate versus remain in evacuation zone, number of persons still at risk, number of persons evacuating	C&D Model	Estimate
Transportation Availability and Options	Methods of evacuation available to evacuees (vehicles, public transport, walking path, bicycles), number of vehicles entering roadway, number of persons without transportation and unable to evacuate the danger zone, potential load on public transit system	C&D Model	Estimate
Work Distance from Home	Number of stops needed before final time and route of evacuation, road congestion	C&D Model, Traffic Model	Yes
School Distance from Home	Number of stops needed before final time and route of evacuate, road congestion	C&D Model	Yes
Medical Assistance	Number of persons needing assistance to evacuate, method of evacuation	Base Maps, C&D Model	Estimate
Road Network	Quality of roads (number of lanes, type of road, speed limit, number of connections to other roads, directionality) will inform areas with the highest risk of becoming trapped due to egress issues,	Base Maps, Traffic Model	Yes

Variable	Information	Use	Available
	potential stations for traffic control personnel at key intersections, segments for improvement; also, directly used in the traffic modeling scenarios		
Road Blockages	Route of evacuees, trap potential, re-routing, resources needed to respond and redirect traffic *It may be possible to derive a scenario for this (distance to fire, fuels along roadway, speed limit, visibility)	Traffic Model	Assumption
Driving Conditions (Visibility)	Traffic speed reduction along routes	Traffic Model	Assumption
Shelter Locations	Number of destinations for evacuees, route of evacuees, shelter capacity, number of people arriving at final destination and leaving the road network, impact to regional communities	Base Maps, C&D Model, Traffic Model	Yes, Limited
Evacuation Perimeter	Number of persons under evacuation, socio-demographic information, transportation options, routes	Base Maps, C&D Model, Traffic Model	Can Calculate
Number of Persons in Evacuation Zone	Number of persons and vehicles evacuating in direct danger, road congestion, shelter capacity, time to reach safe zone	C&D Model, Traffic Model	Can Calculate
Number of Stops	Route taken by evacuees (shortest path is not realistic), congested roads and intersections, and time needed to evacuate	C&D Model, Traffic Model	Assumption
Access to Smart Phone while evacuating	Ability to re-route due to traffic, timely graphical communications, and shelter capacity *Re-routing (Google, Apple maps) may avoid traffic but put users in fire danger areas since map is independent of fire spread projections *Debris and blocked roads may be inferred by traffic, but may not directly display	Traffic Model	Assumption
Shelter Capacity	Number of location-swaps evacuees will make, remove vehicle from road network, re-routing	Traffic Model	Yes, Limited
Communication Updates	Evacuees remaining in safe-zone or returning home	Traffic Model	Assumption
Percent of Persons at Final Location	Number of people likely to continue to non-shelter locations elsewhere, also driven by demographics and income	Traffic Model	Assumption
Regional Preparedness	Background traffic, buildup of evacuation traffic, persons entering evacuation zone unaware, capacity down-route	Traffic Model	Yes